Low Temperature Interconnection of PVD Aluminium Metallization


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Starting point

- Crystalline, mono-facial heterojunction or tunnel-oxide based 6” solar cell in development [1]
- Full-area rear metallization with 150 nm sputtered ZnO:Al and 2 µm thermally evaporated Aluminium [2]
- Due to heterojunction layers, temperature must not exceed 200 °C

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- Task: Find appropriate low temperature interconnection technology
- Challenges: Aluminium and low temperature

How to interconnect (PVD-)aluminium?

Al is difficult to interconnect due to its native oxide

Approaches
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- Laser welding [5]
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- Solderable stacks
  - Jung and Köntges: Al/Ni:V/Ag [6]
  - Kumm: Al/TiN/Ti/Ag [7]
  - Designed for annealing-stability at > 300 °C
  - Tested with SnPbAg solders

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- New approach: TiN is omitted as process temp. remains at max. 200 °C
- Demonstrate interconnection with low temperature methods

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Evaluation of low temperature interconnection methods

Isotropic electrically conductive adhesives (ECA) Sn43Bi57 and Sn41Bi57Ag2-soldering
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Simplified stack: Al/Ag  
(Does it work?)

Two silver-reduced glues are tested
Evaluation of low temperature interconnection methods

Isotropic electrically conductive adhesives (ECA)

- Sn43Bi57 and Sn41Bi57Ag2-soldering

Simplified stack: Al/Ag
(Does it work?)

Two silver-reduced glues are tested

Simplified stack: Al/Ti/Ag

Initial solder tests show, Ti is still necessary as adhesion promoter
Evaluation of low temperature interconnection methods

Isotropic electrically conductive adhesives (ECA)

- Cu ribbon
- Epoxy and metal particles
- Ag capping
- Al wafer + AZO

10 μm

Simplified stack: Al/Ag

(Does it work?)

Two silver-reduced glues are tested

Sn43Bi57 and Sn41Bi57Ag2-soldering

- Sn phase
- Bi phase
- Ti/Ag capping
- Al wafer + AZO

5 μm

Simplified stack: Al/Ti/Ag

Initial solder tests show, Ti is still necessary as adhesion promoter

Assessment program
- Peel tests
- Contact resistance
- Accelerated aging
Samples and characterization

- All tests made at **textured, metallized wafer-level** (no p/n-junction)
- Semi-automatic soldering / curing of ECA
- Peel-tests according to DIN 50461
  - 90° angle, 50 mm/min speed
- Contact resistivity with TLM-structures [8]
- TLM-structures are laminated in glass-EVA-backsheet
- Encapsulated TLM-samples are exposed to thermal cycling and damp heat tests

Peel tests

Soldering

90° Peel Strength [N/mm]

Sn43Bi57
Sn41Bi57Ag2
Sn62Pb36Ag2
Peel tests

Soldering

90° Peel Strength [N/mm]

0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5

Sn_{43}Bi_{57}  Sn_{41}Bi_{57}Ag_{2}  Sn_{62}Pb_{36}Ag_{2}

Glueing

90° Peel Strength [N/mm]

0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5

Ag  Cu  Sn  Glue A  Glue B  Ag  Cu  Sn  Ribbon Coating
Peel tests

- **Low temperature soldering**: 1.5 – 2 N/mm
- **Conductive glueing**: 0.5 – 1 N/mm
- **Similar peel strength of ECA joints with various ribbon coatings**
Contact resistivity
Contact resistivity

- No reduction of FF to be expected if contact resistance remains below 0.5 mΩcm² (3BB, large solder pads) [9]

- Contact resistance of soldered samples is tested before and after lamination (~160 °C)
  - Remelting of solder occurs

- Slight increase of contact resistance for Sn43Bi57 after lamination observed

- Glueing achieves same contact resistance as soldering

Reliability

Thermal aging of soldered interconnections

- Thermal aging is an important reliability test for solder joints [10]
- Metallographic cross sections are isothermally aged in N\textsubscript{2}-atmosphere at 100 °C and 115 °C for 15 h to 155 h
- 100 °C – group is peel tested after aging

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- Metallographic cross sections are isothermally aged in N₂-atmosphere at 100 °C and 115 °C for 15 h to 155 h
- 100 °C – group is peel tested after aging

SnBiAg as soldered

-aged for 85h at 115 °C
-aged for 155h at 115 °C

Reliability

Peel strength of thermally aged interconnections

- Short term thermal aging at 100 °C does not lead to a reduction of peel strength yet
Reliability
Thermal aging of soldered interconnections

SnBiAg solder bond initially

Reliability

Thermal aging of soldered interconnections

- Thin layer of Ag is (at least partly) dissolved in the solder and transformed into Ag₃Sn during initial soldering [11]
- Further thermal aging leads to „spalling“ of Ag₃Sn spheriods [12]
- May effect bond strength in later stages of aging

Reliability
Thermal Cycling

Soldering

<table>
<thead>
<tr>
<th></th>
<th>Sn43Bi57</th>
<th>Sn41Bi57Ag2</th>
<th>Sn62Pb36Ag2</th>
</tr>
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<tbody>
<tr>
<td><strong>Contact Resistivity [mΩcm²]</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>initial</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
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<tr>
<td>TC 200</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
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</tbody>
</table>
Contact resistance of soldered joints on Al/Ti/Ag is stable after TC 200

Increase of contact resistance for one glue, but still below 0.5 mΩ cm²
Reliability
Damp Heat

Soldering

Contact Resistivity [mΩcm²]

Sn43Bi57  Sn41Bi57Ag2  Sn62Pb36Ag2

initial  DH 1000  initial  DH 1000  initial  DH 1000
Reliability Damp Heat

- Contact resistance stable after DH 1000 with soldered interconnects on Al/Ti/Ag except in one case
- Contact resistance of glueing on Al/Ag increases strongly
Observations after damp heat

Adhesive joint before aging
Observations after damp heat

- Partial ablation of Ag capping
- Decomposition of Al layer
- Accumulation of oxygen in the Al layer (determined via EDX)
- Simplified stack Al/Ag is not reliable to interconnect
Conclusions

- Demonstration of interconnections on a simplified solderable Ti/Ag stack on PVD-aluminium
  - Peel forces with SnBi and SnBiAg above 1 N/mm and good electrical contact
  - No degradation of resistance after first environmental chamber tests
- Simple Ag-capping of Al:
  - No peel strength for soldering
  - Peel strength of glueing 0.5 – 1 N/mm good in the expected range
  - Contact resistance is as low as soldering
  - **But:** Increase of contact resistance in damp heat observed
  - Desintegration of layer and oxygen accumulation observed
  - Modification of stack is required
Thank you for your attention!

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